18

Protein-Energy Malnutrition

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More than 500 million people are unable to meet their energy and protein requirements for an active and healthy life. They are almost all poor and most of them live in developing countries, particularly in South Asia and Africa. They cope with the deficiency by reducing energy and protein expenditure in growth, work, and leisure. As a result of growth faltering, the weight of about 170 million preschool children, or about one-third of all preschool children, is currently below two standard deviations of normal healthy weight for children at their age; they suffer from protein-energy malnutrition (PEM) and related diseases. About 24 million infants are born underweight (weighing less than 2.5 kilograms) each year, in large measure because of PEM in women during pregnancy and before.

About 5 million infants are unable to cope with growth faltering and low birth weight resulting from PEM and associated diseases; they die before they reach the age of five. This amounts to about one-third of all deaths of preschool children in developing countries. In addition, PEM during childhood and adulthood increases the cost of health and education and reduces school performance, labor productivity, and general economic growth. The estimated economic losses worldwide resulting from reduced labor productivity alone are $8.7 billion annually. Thus, although the contribution to child mortality is very serious indeed, it is only part of the damage that PEM is doing to individuals, households, and nations.

Protein-energy malnutrition is a result of either infectious diseases or insufficient intake of energy and protein or—most commonly—a combination of the two. Each of these two immediate causes of PEM is influenced by a number of factors, including sanitary conditions, the quantity and quality of water available, access to primary health care, household behavior, and access to resources. Although child care, breastfeeding, and weaning practices are of particular importance in avoiding PEM among children, poverty and lack of access to appropriate primary health care are the overriding constraints to good nutrition at the household level.

Some single interventions, including food supplementation for preschool children and pregnant women, have been successful in alleviating PEM in a cost-effective manner. Thus, the cost of perfectly targeted food supplementation for preschool children and pregnant women per child life saved was estimated at $1,942.00 and $733.00, respectively. These estimates correspond to $40.00 and $23.65 per disability-adjusted life-year; costs that compare favorably with the costs associated with interventions in the health area and reported in other chapters of this book. Food supplementation is also justified on grounds of economic efficiency. The benefit-to-cost ratio of food supplementation of preschool children was estimated to be 17.4, implying a return of $17.40 for each dollar invested in such programs after discounting for differences in the timing of investment and returns. Other successful single interventions include nutrition education based on the concept of social marketing in Indonesia and the Dominican Republic, and promotion of breastfeeding in several countries.

Still, because PEM is frequently a result of many interacting factors, the effect of single interventions may be limited. Integrated programs that are designed to deal with the adverse factors identified for a particular population and for which the necessary national and local capacity and infrastructure for program implementation exist or can be developed are likely to be more successful than single interventions. Several such integrated programs, including the Tamil Nadu Integrated Nutrition Program in India and the Iringa Program in Tanzania, have dramatically reduced PEM in preschool children in the program areas.

To be successful, efforts to alleviate PEM must be based on a solid understanding of the environment within which the nutrition problem exists, the factors causing the problem, and feasible solutions. Such understanding is best obtained by direct participation of intended beneficiaries in program design and implementation. Furthermore, a strategy to alleviate PEM should consider direct and indirect interventions as well as broader government policies, which, although not directed at nutrition, may have a significant nutritional effect.

The Public Health Significance of PEM

Three indicators are commonly used to estimate the prevalence of protein-energy malnutrition: (a) protein and energy intake in relation to requirements; (b) growth, weight, and height in relation to established standards; and (c) birth weight. Because PEM results from either insufficient intake of energy and protein or infectious diseases, or most commonly a combination of the two, the first indicator measures a critical determinant of the nutritional status rather than nutritional status itself. An intake of energy and protein adequate to meet requirements is necessary but not sufficient to alleviate PEM.

The combined effect of energy and protein intake and the prevalence of infectious diseases is reflected in the rate of growth of children and in the weight in relation to height in adults. Birth weight may be used as an indicator of the nutritional status of women during pregnancy and before. The three sets of indicators mentioned above are widely used for estimating the prevalence of PEM in populations, and they are the only ones for which information is available at country and international levels.

The interpretation of the figures for energy and protein intake for the purpose of estimating the prevalence of PEM is further complicated by variations in energy requirements among individuals and over time and by unobserved adjustments in energy expenditure, whether in response to intake or not. Individuals are considered undernourished when their energy intake is less than the minimum required to maintain good health and desired activity. The Food and Agriculture Organization (FAO) suggests that the minimum energy requirement for adults is 1.2 to 1.4 times the basal metabolic rate (FAO 1987).[1]

Although the rate of growth is a better indicator of the current nutritional status of children than attained weight or height in relation to the genetic potential for a particular age (usually reported as weight-for-height, height-for-age, and weight-for-age), the former is not usually available for populations. Children whose weight-for-height is below two standard deviations of growth standards for a well-nourished population are considered "wasted," implying malnutrition resulting from recent or current deficiencies in nutrient intakes or infectious diseases or both. Children whose height-for-age is below two standard deviations of growth standards are considered "stunted," implying malnutrition resulting from past or longer-term deficiencies or infections or both. Low weight-for-age, frequently the only available measure of malnutrition, may be evidence of wasting or stunting or both (WHO 1986).

PROTEIN AND ENERGY DEFICIENCIES. Using the cutoff point of 1.2 times the basal metabolic rate, which, as already mentioned, is likely to fall considerably below desirable energy intake levels, the FAO (1987) estimated that about 335 million people were undernourished during the period 1979–81, up from 325 million ten years before. In relation to the total population of the developing countries, however, the percentage of those undernourished decreased from 19 percent to 15 percent during the ten-year period (table 18-1). Using the same cutoff point, the Subcommittee on Nutrition of the Administrative Committee on Coordination (ACC/SCN) of the United Nations estimates that the number of undernourished people had increased to 360 million by 1983–85 (United Nations 1987). Updating these estimates with the 1989 population figures and adding a rough estimate of food poverty in China, Chen (1990) estimates that in 1989, 465 million people lived in households too poor to obtain the energy necessary for minimal activity among adults and for the healthy growth of children. A more recent ACC/SSN publication (United Nations 1992) estimates that 786 million people were consuming less than 1.54 BMR by the end of the 1980s, down from 976 million in the mid-1970s.

As shown in table 18-1, the majority of undernourished individuals are found in Asia—notably South Asia—although when the number of undernourished people are measured in relation to total population, the problem appears to be slightly more severe in Africa. During the 1970s, the prevalence of undernourished people increased considerably in Africa, decreased in the Near East, and remained almost constant in Asia and Latin America. No reliable data are available by region for the period since 1981.

ANTHROPOMETRY-BASED ESTIMATES. The authors of a recent study for the United Nations Children's Fund (UNICEF) estimate that 150 million children below the age of five years in developing countries, excluding China, or 36 percent of all such children, are underweight, that is, below two standard deviations of standard weight-for-age (Carlson and Wardlaw 1990). Chen (1990) estimates that the prevalence in China is 18 million, which, added to the number in the developing countries, yields a total of 168 million for the world as a whole. In 1992 the United Nations ACC/SCN estimated that this num-

Table 18-1. Undernourished Population of Developing Countries, by Region, 1969–71 and 1979–81

Region	*Total population (millions)* 1970	1980	*Undernourished population[a] (millions)* 1969–71	1979–81	*Proportion of population undernourished (percent)* 1969–71	1979–81
Africa	282	376	57	70	20	19
Far East	986	1,232	208	210	21	17
Latin America	278	357	36	38	13	11
Near East	159	210	23	16	15	8
Total[b]	1,708	2,179	325	335	19	15

a. 1.2 times BMR for adults and adolescents.
b. Ninety-eight developing market economies.
Source: FAO 1987.

Table 18-2. Prevalence of Malnutrition in Children under Five in Developing Countries

Region	Underweight[a]		Stunting[b]		Wasting[c]	
	Millions	Percent	Millions	Percent	Millions	Percent
Africa	29	26.6	39	35.3	11	10.2
South Asia[d]	73	45.2	66	41.3	16	9.8
Rest of Asia[e]	40	43.4	43	46.2	7	8.3
Americas	8	13.8	15	27.7	1	1.3
Total[e]	150	35.7	163	39.0	35	8.4

a. Children more than two standard deviations below the reference median for weight-for-age.
b. Children more than two standard deviations below the reference median for height-for-age.
c. Children more than two standard deviations below the reference median for weight-for-height.
d. Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka.
e. Excluding China.
Source: Carlson and Wardlaw 1990.

ber was valid for the mid-1970s and that it had increased to 184 million (34 percent) by the end of the 1980s. According to Carlson and Wardlaw, stunting is more prevalent than underweight, whereas wasting is estimated to affect about 35 million children, or about 8 percent of all children under the age of five years in developing countries, excluding China (table 18-2). As shown in table 18-3, more than 15 percent of the underweight children are severely underweight. Severe stunting affects more than 40 percent of all stunted children.

Underweight and stunting are more prevalent in Asia than in the other regions both in absolute numbers of affected individuals and in relation to all children who are malnourished. When measured in relation to the total population of children, wasting is most prevalent in Africa. This is undoubtedly a reflection of the deterioration of the African food situation during the late 1970s and the 1980s. Comparisons between the above figures and estimates reported by the FAO (1987) in the Fifth World Food Survey support the notion of deterioration in the nutritional situation in Africa. More recent developments including widespread famine indicate further deteriorations. Thus, based on a direct comparison of continents, it appears that the prevalence of wasting among African children below the age of five has increased from 4 million to 11 million children, or from 7 to 10 percent of all such children in the region, whereas the absolute prevalence stayed constant for Asia and decreased in Latin America. In view of the differences between the two sets of estimates with regard to data sources and methods, the results of such direct comparisons are prone to large errors and should be interpreted as only rough indications of change in the prevalence by region.

Table 18-3. Prevalence of Severe and Moderate Malnutrition
(percent)

Indicator of malnutrition[a]	Severe[b]	Moderate[c]	Total	Severe malnutrition as percentage of severe and moderate
Underweight	5.6	30.7	36.3	15.4
Stunting	14.5	20.9	35.4	41.0
Wasting	0.8	5.4	6.2	13.4

a. Underweight refers to low weight-for-age. Stunting refers to low height-for-age. Wasting refers to low weight-for-height.
b. More than three standard deviations below the median for the reference population.
c. Two to three standard deviations below the median for the reference population.
Source: Carlson and Wardlaw 1990.

The prevalence of malnutrition among preschool children is generally higher in rural than urban areas. Thus, in an examination of data from ten countries, Kates and others (1988) found that the prevalence of underweight in rural children was 1.4 to 2 times the prevalence in their urban counterparts. This finding was confirmed by Carlson and Wardlaw (1990), who found that the prevalence of underweight in preschool children was higher in rural than in urban areas of all thirty-one countries studied. On the average, the rural prevalence was 1.6 times the urban prevalence.

The average rural prevalence of stunting was 1.5 times the urban prevalence, and all but one country shows a lower prevalence in urban than in rural areas. Wasting showed a different pattern, with almost one-third of the thirty-one countries having a higher prevalence in urban areas. On the average, the rural prevalence exceeded the urban prevalence but only by a factor of 1.2. Although a firm interpretation of this finding must await further research, it may be hypothesized that the smaller difference between urban and rural areas with respect to wasting, which indicates more recent nutrition insults, than with respect to stunting is an indication of a shift of the nutrition problem from rural to urban areas. The shift is due to rural-to-urban migration and deterioration in urban living standards, including reduced real wages, higher food prices, reduced government expenditure on primary health care, and increased unemployment, resulting from the economic crises and associated macroeconomic policy reforms currently undertaken in most developing countries.

Children are generally exposed to the highest risk of PEM and associated mortality during and immediately following the weaning period, that is, between six months and twenty-four months of age. It is during this period that the prevalence of underweight and wasting is the highest. Beyond the age of two years, the prevalence of wasting usually drops off sharply and the prevalence of stunting is maintained, reflecting a lack of catch-up growth and a reduced risk of acute malnutrition beyond the age of two years. These relationships are illustrated in table 18-4.

The prevalence of low birth weight is an indicator of malnutrition among women during pregnancy and before. Chen (1990) estimates that about 24 million infants are born underweight (defined as weighing less than 2.5 kilograms) every year. This figure corresponds to 16 percent of all births globally. The problem is most prevalent in Asia, where an estimated 29 percent of all infants are born underweight as compared with 16 percent in Sub-Saharan Africa, 11 percent in Latin America and the Caribbean, and 7 percent in the United States (McGuire 1988).

Functional Consequences

The large magnitude of malnutrition in developing countries has serious functional consequences for the affected individuals and their families as well as economic consequences for individuals, households, and nations. Although the ultimate consequence of malnutrition is death, increased mortality is only one of many reasons why malnutrition is undesirable and costly. Protein-energy malnutrition in children inhibits their growth, increases their risk of morbidity, affects their cognitive development, and reduces their subsequent school performance and labor productivity. In women during pregnancy and before, PEM contributes to morbidity and mortality and to low birth weight of their infants, which in turn increases the risk of malnutrition and mortality in infants. Such increased risk is also associated with PEM in women during lactation. Work capacity and labor productivity in adults are negatively affected by PEM during childhood and adulthood, and the economic consequences of PEM are the sum of these productivity losses, additional costs of health and other social programs necessitated by malnutrition, lower school performance, higher educational costs, and lost productivity of care givers because of child malnutrition.

Table 18-4. Prevalence of Malnutrition by Age
(percent)

Age (years)	*Underweight*	*Stunting*	*Wasting*
Less than one	14.7	18.0	4.8
One	30.4	35.3	9.4
Two	26.6	33.5	5.1
Three	24.1	34.5	3.4
Four	23.2	35.3	3.6

Note: For thirty-nine countries. Underweight refers to low weight-for-age; stunting refers to low height-for-age; wasting refers to low weight-for-height.

Source: Carlson and Wardlaw 1990.

MORTALITY AND MORBIDITY. According to estimates made by UNICEF (1988), PEM is a contributing cause of the deaths of about one-third of the 15 million children that die annually. In view of the complex interactions between PEM and diseases that play a role in child mortality, the effect of PEM is difficult to isolate. The relation between low birth weight and child mortality is well documented (Ashworth and Feachem 1985; Herrera 1985; Rasmussen and others 1985; Kramer 1987). The pattern of risk is associated with the length of gestation and size at birth. Mortality in the first year of life appears to be greater for premature infants than for those who are full-term but suffer intrauterine growth retardation (IUGR). The mortality risk for children age one to four years, however, is greater for infants with IUGR (Ashworth and Feachem 1985). In developing countries, as much as 80 percent of low birth weights are due to chronic IUGR, rather than premature birth (Villar and Belizan 1982; Villar and others 1986; WHO 1986; Puffer and Serrano 1987). The growth potential of infants with chronic IUGR is restricted because of the severity and length of in utero deficits (Villar and others 1984, 1986). Among low-birth-weight infants who are premature or suffered acute IUGR, catch-up growth is rapid in the first six to eight months of life (Davies and others 1979; Villar and others 1984; Peterson and Frank 1987) but only if nutritional supplies are adequate.

The attainable birth weight of infants of women who are stunted as a result of childhood malnutrition is constrained, and thus the lifelong cycle of chronic growth deficits is perpetuated (Herrera 1985). In developing countries, maternal height makes a significant independent contribution to birth weight, an effect mediated through IUGR, not prematurity (Kramer 1987). The coefficient for maternal height independent of weight on birth weight is approximately 7.8 to 10 grams per centimeter of mother's height (Thompson, Billewicz, and Hytten 1968; Tanner and Thompson 1970; Kramer 1987). In longitudinal studies of children in developing countries, maternal height predicted both height-for-age and weight-for-age in the second and third years of life, independent of other biological and social risk factors (Mata 1978; Balderston and others 1981; Kielmann and others 1983).

In epidemiological studies of the short-term mortality risk among hospitalized children, the proportion of deaths was significantly greater among severely malnourished children than among those who were moderately malnourished (Gomez and others 1956; McLaren and others 1969). Prospective community-based studies (Kielmann and McCord 1978; Chen and others 1980; Kasongo Project Team 1983; Bairagi and others 1985; Lindskog and others 1988; Yambi 1988) have generally demonstrated an increase in risk of death at weights-for-age less than 70 to 80 percent of the reference median (Kielmann and McCord 1978) and a sharp increase in mortality risk at weights-for-age less than 60 percent of the median, weights-for-height less than 70 percent of the median, and heights-for-age less than 85 percent of the median (Kielmann and McCord 1978; Chen and others 1980; Lindskog and others 1988; Yambi 1988). Children who were both severely wasted and stunted were at the greatest risk of death (Chen and others 1980).

Growth faltering (Bairagi and others 1985) and arm circumferences less than 75 percent of median (Sommer and Lowenstein 1975) also predicted increased mortality risk. Mortality rates and the predictive ability of nutrition indicators varied by age (Kielmann and McCord 1978; Kasongo Project Team 1983) and were greater among children of lower socioeconomic status and born to shorter and lighter mothers (Chen and others 1980; Chowdhury 1988). A recent synthesis of studies of the relation between child anthropometry and mortality indicates that the relationship holds even for mild to moderate malnutrition (Pelletier 1991a).

Numerous studies have shown an association between malnutrition and infectious disease, especially diarrhea, among children in developing countries. Only a limited number of the researchers, however, used longitudinal analyses to examine nutritional status as a predictor of diarrhea and infections; even fewer controlled for other factors associated with PEM that may have contributed to infections.

Among studies in which measurements of diarrhea incidence and duration over intervals of two to three months were included, malnutrition predicted either increased duration (Tompkins 1981; Black, Brown, and Becker 1984) or incidence (El Samani and others 1988; Sepúlveda, Willett, and Muñoz 1988) of diarrhea. This relationship remained constant when previous diarrhea and sociodemographic variables were controlled in the analysis (Ghai and Jaiswal 1970; Sepúlveda, Willett, and Muñoz 1988). Anthropometric deficits did not predict incidence of diarrhea among preschool children in two studies in which incidence over intervals of nine months or longer were measured (Chen, Huq, and Huffman 1981; Peterson and others 1988b). Thus, the evidence suggests that malnutrition in preschool children in developing countries predicts short-term risk of increased incidence and duration of diarrhea, but prediction of long-term risk has not yet been demonstrated. In addition, the evidence for a causal role of child malnutrition in other infectious diseases, including measles, malaria, and acute respiratory infections merits longitudinal analysis.

COGNITIVE DEVELOPMENT. Growth retardation affects the development of motor and mental functions. Severe PEM affects brain growth, attention span, and short-term memory as well as activity level, which in turn affects interaction with the care giver and the environment (McGuire and Austin 1987). Because of the interaction between sensory environment and PEM-induced growth failure, Pollitt (1987) suggests that cognitive development is best understood as the outcome of the social environment and health history and the interaction of these variables with the nutritional status of children. It appears that psychosocial stimulation often can override or minimize the effects on the cognitive potential resulting from PEM.

In developing countries, early malnutrition has been associated with later developmental delays among children (Pollitt 1987); but most of the variability in intelligence quotients (IQs) was explained by differences in socioeconomic status (Richardson 1980). Among severely malnourished Korean preschool children who were adopted into American homes, the mean IQ score at school age exceeded the average score for American children and was forty points higher than that reported for children from similar populations who were returned to their home environment (Winick and others 1975). Several studies have shown that children in industrial countries who suffered early malnutrition secondary to organic illness, independent of socioeconomic deprivation, did not exhibit low developmental or intelligence test scores at later ages (Pollitt 1987). Interventions that provided food alone to children at risk of PEM resulted in mild to insignificant improvements on cognitive development. In contrast, those interventions that combined health care and educational or psychosocial stimulation with nutritional supplementation appeared to have a significant effect on cognitive development (McKay and Sinisterra 1974; Cremer and others 1977; McKay and others 1978; Grantham-McGregor and others 1979; Grantham-McGregor, Stewart, and Schofield 1980; Grantham-McGregor, Schofield, and Harris 1983).

SCHOOL PERFORMANCE. Sensory deprivation because of PEM in preschool children results in impaired learning abilities, adverse behavior, poor school attendance, and grade repetition. On the basis of a review of more than fifteen studies undertaken in various developing countries and the United States, McGuire and Austin (1987) conclude that "better growth is associated with better preschool and school-age I.Q. It is also associated with learning-relevant behavior, early enrollment in school and better school achievement, all of which enhance the educational efficiency of and economic return on primary schools." Similarly, the ACC/SCN concludes that "Malnutrition and infection during the preschool period, interacting with environmental factors related to poverty, are critical determinants of later school performance" (United Nations 1990).

LABOR PRODUCTIVITY. Evidence from small controlled experiments show a clear causal relation between body size, aerobic capacity, and physical work capacity (Spurr, and others 1977; Spurr 1983, 1984). Because the strenuous work undertaken by a large share of the labor force in developing countries requires a great deal of physical energy, it seems reasonable to assume that the link between body size and work capacity would be reflected in a strong link between body size and labor productivity. Similarly, a strong link between energy intake of adults and their labor productivity would be expected. Evidence of both links have been found in a number of studies as reviewed by Martorell and Arroyave (1984), Latham (1985), Strauss (1985), Agarwal and others (1987), McGuire and Austin (1987), and Berg (1987). Methodological flaws in the results of many of the studies reviewed, however, make the interpretation of the findings difficult (Strauss 1985).

Four recent studies appear not to suffer from serious methodological flaws. Strauss (1986), in a study of a sample of farmers in Sierre Leone, and Sahn and Alderman (1988), in a study of Sri Lankan households, found a significant relation between household-level energy consumption and labor productivity. Neither of the two studies had data available on the height and weight-for-height of the workers and their individual energy consumption. Thus, the effects of nutritional status in childhood, past energy consumption during adulthood, and current energy consumption cannot be separated. Such separation was done by Deolalikar (1988) in a study of South Indian households. He found that labor productivity as measured by attained wages and farm output was highly responsive to weight-for-height of the worker. No such response was found with respect to height and contemporary energy intake. Thus, although more research is needed, it may be hypothesized that weight changes provide a buffer between changes in energy intake and labor productivity. The immediate effect of reduced energy intake is weight loss, which if continued will subsequently influence labor productivity.

Haddad and Bouis (1990) found a strong effect of childhood nutritional status—as represented by height—on the labor productivity of Philippine agricultural workers. The elasticity of height on productivity—as measured by wage—was estimated to be 1.38, implying that a difference of 1 percent in the height of adult workers is associated with a 1.38 percent difference in their wages.

The findings from the four studies are powerful because they permit an estimation of the economic losses associated with malnutrition. Taken with estimates of cost-effectiveness of various programs, they make it possible to estimate the net economic gains associated with efforts to alleviate malnutrition. A preliminary estimate of this nature is made in the next section. Still, more research is needed to verify these findings and to develop empirical evidence for various settings to strengthen the validity of such estimates.

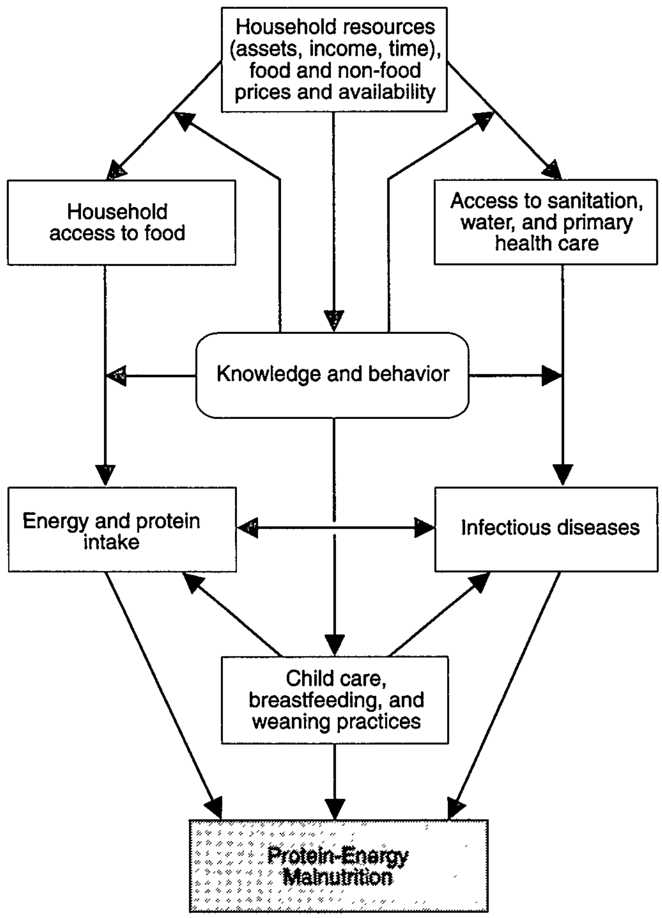
ECONOMIC COSTS. On the basis of the Haddad and Bouis estimates discussed earlier, a rough preliminary estimate can be made of the economic losses resulting from forgone labor productivity due to PEM. According to tables 18-2 and 18-3, stunting affects 163 million preschool children, of which 41 percent are severely stunted. After the age of about twenty-two months, severely stunted children are 10 centimeters shorter than the median, whereas moderately stunted children are 7 centimeters shorter (WHO 1979). Stunting during childhood appears to translate to equal height deficiencies in adulthood (Martorell, in press). Assuming an average daily wage of $2.50 and 300 working days per year for the workers exposed to stunting in childhood and an average height of 160 centimeters (the average height of the Philippine sample on the basis of which Haddad and Bouis estimated the above-mentioned relation between height and productivity), we find that the total economic loss due to stunting is $8.7 billion annually, or about one-fourth of the total health expenditure of developing countries (see appendix 18A for the methodology used in the calculation).

In addition to the economic costs associated with nutrition-related mortality and productivity losses, household incomes and national economic growth are negatively influenced by PEM through higher costs of or lower benefits from education, higher health costs, higher costs of social programs, and income losses as a result of care giving in households with malnourished members. No quantitative estimates are available for these costs.

Causes of PEM

Protein-energy malnutrition is caused by infectious diseases and insufficient intake of energy and protein to meet requirements (figure 18-1). The effect of each of the two is a function of the state of the other, and most individuals who suffer from PEM do so because of exposure to both. The prevalence and severity of infectious diseases are influenced by sanitary conditions, quality and quantity of water available, access to primary health care, behavior of households and individuals, energy and protein intake, and, in the case of children, by child care, breastfeeding, and weaning practices. Energy and protein intake is influenced by household access to food, food acquisition and allocation behavior, infectious diseases, and the three child-related factors mentioned above. Access to food, sanita-

Figure 18-1. Principal Factors Affecting PEM



Source: Authors.

tion, water, primary health care, and knowledge is in turn influenced by household resources, that is, assets, income, and time, as well as the prices and availability of food and nonfood goods and services, including health care services at the community level.

Infectious Diseases

The effect of infection, especially diarrhea, on the nutritional status of poor children in developing countries has been well documented (Beisel 1977). Mechanisms by which diarrhea and other infections cause malnutrition include decreased food intake resulting from anorexia or food withholding, decreased nutrient absorption, increased metabolic requirements, and direct nutrient loss (Chen 1983; Keusch and Scrimshaw 1986). Epidemiological studies have demonstrated a negative relationship between infections—above all, measles, diarrhea, and malaria—and concurrent child growth in Latin America (Mata and others 1972, 1977; Martorell and others 1975; Mata 1978), Africa (Rowland and others 1977, 1988; Whitehead 1977) and Asia (Koster and others 1981; Kielmann and others 1983).

Evidence for the effect of respiratory infections on nutritional status is equivocal. No association has been reported by several authors (Rowland and others 1977; Whitehead 1977; Martorell and others 1975, 1983), although respiratory illness had as strong an effect as diarrhea on weight loss in Brazilian children (Leslie 1982). A recent longitudinal study (Rowland and others 1988) showed that lower respiratory tract infections were significantly associated with rate of weight gain in Gambian infants. After adjusting for the prevalence of disease, such infections accounted for one-quarter and diarrhea for one-half of the shortfall in attained weight compared with reference standards.

Intervention trials reviewed by Stephenson (1987) have pointed to the contribution by a number of parasitic infections to childhood growth retardation. With chemotherapy, children with parasitic infections showed small improvements in rate of weight gain, weight-for-height, and subcutaneous fat stores (Stephenson 1987). Other infections have not been shown to affect growth significantly, including infectious fevers (pertussis, chicken pox), skin and eye infections, and deep infections requiring antibiotic treatment (Martorell and others 1975; Rowland and others 1977; Whitehead 1977). Sample sizes for some of these studies were too small to pick up an effect, however, except for skin and eye infections.

The relative effect of infections and inadequate energy and protein intake on the growth of children in developing countries varies with the prevalence of infection (Martorell and Yarbrough 1983; Keusch and Scrimshaw 1986). In prospective studies, diarrhea incidence predicted height-for-age during periods of peak incidence, in the second and third years of life (Mata 1978; Balderston and others 1981; Kielmann and others 1983; Lutter and others 1989), but it did not explain variance in the weight or height of children studied before (Peterson and others 1988a) or after (Leslie 1982) the period of peak incidence. Caloric intake (Balderston and others 1981) and weaning practices (Balderston and others 1981; Mata 1978) were as important as or more important than diarrhea incidence in multivariate models that explained variance in weights and heights of children from twelve months to thirty-six months of age. New findings from data collected in the 1970s in Guatemala and Bogotá indicate that the pernicious effect of diarrhea on growth is not seen if children are better fed during periods of diarrhea (Martorell, Rivera, and Lutter 1988; Lutter and others 1989; Rivera, Martorell, and Lutter 1989).

Energy and Protein Intake

Insufficient energy and protein consumption to meet desired expenditure results in reduced rate of growth, weight loss, reduced level of activity, or a combination of these. In children, the rate of growth is sensitive to both deficiency in intake and infection. Because of the synergistic relationship between food intake and infectious diseases, the expected growth response to improvements in one of the two may not be observed. Recent multivariate analyses have separated the effects of the two and shown strong growth responses to one or the other or both, depending on the context (Kennedy 1989; Von Braun, Puetz, and Webb 1989).

Child Care, Breastfeeding, and Weaning Practices

On the basis of a review of available literature, Huffman and Steel (in press) conclude that "few interventions have been shown to be as effective in preventing diarrhea among infants as breastfeeding." In view of the strong relation between diarrhea and PEM, this conclusion has obvious nutritional implications. Community- and hospital-based studies in a number of countries, including Brazil (Victora and others 1987), Peru (Brown and others 1988), Indonesia (Lambert 1988), India (Anand 1981), Costa Rica (Mata 1983), and the Philippines (Clavano 1982), all show that breastfeeding reduces the occurrence of diarrhea.

As discussed earlier, children are exposed to the highest risk of malnutrition and growth faltering during the weaning period from the age of six months to twenty-four months. Weaning foods commonly used are inadequate supplements to nutrients in breast milk and a source of contamination, contributing to an increased incidence of infectious disease (Scrimshaw and others 1968; Wyon and Gordon 1971; Barrell and Rowland 1979; Black and others 1982). Thus, where fecal contamination of the environment is widespread, prolonged full and partial breastfeeding is particularly important (Habicht and others 1988). In Brazil, delaying the introduction of solids promoted better growth in the first five months among the urban poor who had limited access to flush toilets, piped water, and refrigeration, presumably through reduced incidence of infectious disease. A recent study of infant feeding practices in a region of the Republic of Yemen that had a high prevalence of both acute and chronic PEM showed that breastfeeding had the strongest beneficial effect on weight-for-length and weight-for-age of infants age three months to six months (Jumaan and others 1989). The introduction of other foods was positively associated with weight-for-length only among children twelve to twenty-three months of age.

Child care is also of paramount importance during this period and beyond. Maternal child-rearing behaviors and attitudes, mother-child interaction, family social relationships, and stress have been associated with poor nutritional status in both industrial and developing countries in theoretical models (Williams 1962; Klein and others 1972; Caldwell 1974; Mata 1978; Herrera and others 1980; Rathbun and Peterson 1987). Maternal interaction with both family- and community-based networks has been associated with child growth outcomes in cross-sectional and longitudinal (Peterson and others 1988a) studies, suggesting that social support for the mother may be an important aspect of caretaking capacity and resourcefulness. These and related issues are further analyzed by Engle (in press).

Knowledge and Behavior

There is a strong association between maternal education and child nutrition and mortality, although the specific mechanisms through which the association operates is not fully understood (Leslie, in press). On the basis of a comprehensive review of available evidence, McGuire and Popkin (1990) conclude that the nutrition effects of maternal education are mediated through better management of household resources, greater use of available health care services, health behavior that compensates for a lack of such services, lower fertility, and more child-centered care-giving behavior.

Maternal Health and Reproductive History

Inadequate food availability to meet energy demands may adversely affect the health and nutritional status of mothers as well as that of their offspring. Maternal stunting due to early malnutrition and concurrent energy deficits can limit maternal work productivity and birth length and weight of the infant (Kramer 1987). Evidence suggests that the repeated demands of many pregnancies and close child spacing may deplete maternal nutritional status (Hamilton and others 1984; Merchant and others 1988), although further studies are needed on this topic. A large number of young children in the home may also adversely affect the nutritional status of the individual child (Kielmann and others 1983), independently of family socioeconomic status and maternal health and reproductivity history (Peterson and others 1988a), presumably because maternal time for child care and feeding must be shared by many.

Access to Sanitation and Water

Improved water and sanitation may affect PEM through a reduction in the transmission of pathogens, which in turn reduces diarrheal diseases. In addition, improved access to water may affect PEM by reducing the time needed to acquire the water—usually a task performed by women and children—and by making more water available for household production of food (Burger and Esrey, in press).

Recent reviews (Esrey, Feachem, and Hughes 1985; Esrey and Habicht 1985, 1986; Esrey and others 1990; and Burger and Esrey, in press) found that improved water and sanitation are associated with decreased diarrheal diseases, improved nutritional status, and lower childhood mortality. The effect of improved water and sanitation on child morbidity and growth depends on the existing environmental conditions and the presence or absence of other related factors and programs that influence exposure to pathogens (Burger and Esrey, in press). For example, in Malaysia the introduction of flush toilets and piped water was found to have a greater effect on the mortality of nonbreastfed than breastfed infants, because breastfeeding reduced the exposure to pathogens (Habicht and others 1988). Similar interactions were found between improved water and sanitation and income and educational levels in several countries (Burger and Esrey, in press). On the basis of a review of past interventions, Esrey and Habicht (1986) conclude that water quantity has a greater effect on child morbidity than water quality in contaminated environments and that improved water quality may have little effect unless most other important routes of contamination are eliminated.

Evidence from several countries indicates that improved access to water increases the amount of time women spend on food production, processing, and preparation (Burger and Esrey, in press). Time saved in water collection may also be used in improved child care, income-generating activities, and other nutrition-related activities.

Household Access to Food

Household access to food is closely related to food consumption by individual household members, but intrahousehold food allocation does not necessarily parallel relative needs. Patterns of intrahousehold food distribution have been reviewed by several authors (Den Hartog 1972; Van Esterik 1984; Haaga and Mason 1987). Findings of preferential distribution of family food by age are equivocal and difficult to interpret because of differences in the outcome measures and the recommended dietary allowance schedule used (Haaga and Mason 1987).

The authors of some studies have shown that the adequacy of energy intake was greater in adults than for preschool children (Aligaen and Florencio 1980; Nutrition Economics Group 1982; Pinstrup-Andersen and Garcia 1990), whereas others demonstrated that children received a greater proportion of their recommended dietary allowance than adults (Nutrition Economics Group 1982; Van Esterik 1984), especially if total intake from both meals and snacks was computed (Harbert and Scandizzo 1982). The adequacy of the energy intake of children in relation to that of adults is influenced by family income and seasonal effects, including food shortages, lack of maternal time for child care and feeding, and the need for food for agricultural workers (Van Esterik 1984). Other feeding practices that may influence PEM in children include withholding solids from them during diarrhea (Taylor and Taylor 1976) and feeding them staples that have low energy density.

A sex bias in food distribution that favors males has been documented in the Middle East and South Asia (Van Esterik 1984; FAO 1987; Haaga and Mason 1987), whereas no such bias was found in Africa (Svedberg 1989; Von Braun, Puetz, and Webb 1989). The sex bias in South Asia is particularly important and deserves serious attention because of the high rates of malnutrition in that region. Differences in weaning and access to food (Van Esterik 1984) may be reflected as well in patterns of malnutrition and mortality (DeSweemer 1974; Chen and others 1980; Chen, Huq, and D'Souza 1981). A sex bias in food distribution is usually related to other factors, including age, lactation and pregnancy, birth order and sex of child in relation to siblings, maternal education, and family income (Abdullah 1983; Van Esterik 1984; Haaga and Mason 1987). Patterns of sex bias in food distribution and in nutritional and health status and survival may also be related to regional ecology, which determines the agricultural economy and the demand and perceived value of male as opposed to female labor (MacCormack 1988). Societies with an ideology of matrilineal descent (and greater investments in health and nutrition of women) seem to be found in high rainfall areas, which require labor-intensive hoe cultivation, whereas patrilineal descent is traditionally seen in dry-land plow regions of continents (MacCormack 1988).

Household Resources and Prices

Poverty is the most important determinant of PEM because it constrains household access to food, knowledge, sanitary living conditions, safe water, and appropriate health care (figure 18-1). Increasing household income among the poor results in expanded energy and protein consumption, stronger demand for education and health care, and improved living conditions (Pinstrup-Andersen 1985; Garcia 1988), although the effect of increases of income on energy consumption may be less than previously expected (Behrman 1988). Similarly, households respond to food price changes by adjusting household food consumption (Pinstrup-Andersen 1985).

As discussed above, changes in household food consumption influence that of high-risk household members, which in turn influences their nutritional status. Thus, evidence of causal effects for each of these steps implies a causal effect between income and nutritional status. Several researchers, including Garcia (1988) in the Philippines, Alderman (1990) in Ghana, and Sahn (1990) in Côte d'Ivoire, found a strong association between income changes and the nutritional status of preschool children. In addition to the importance of the absolute level of incomes and prices, fluctuations in incomes and prices, including seasonality, are important determinants of PEM in many rural areas (Payne 1985; Sahn 1989) and may influence intrahousehold allocation of food (Van Esterik 1984).

The effect of higher incomes on nutrition may be insignificant in the short run in areas in which poor sanitation and lack of knowledge and primary health care are the most limiting constraints to good nutrition. In the longer run, however, higher incomes are likely to alleviate these constraints.

Interventions for Control of PEM

The factors that influence the two basic causes of PEM (inadequate intake of energy and protein and infectious diseases) may be manipulated by various interventions. In table 18-5 we list the most important factors, interventions, and related activities. Only the interventions related to intake will be discussed in this chapter.

Single Interventions to Improve Dietary Intake

Single interventions reviewed here include food supplementation of children and women as well as food price subsidies, income transfers, food fortification, and other broad programs and policies.

FOOD SUPPLEMENTATION. Food supplementation schemes are usually not designed in such a way as to permit credible evaluation of effect. Therefore, results from evaluation attempts such as those reported by Beaton and Ghassemi (1982) are difficult to interpret and do not permit inference regarding the biological effects per unit of food supplement. The synthesis undertaken here is limited to food-supplementation schemes designed in such a way as to permit a reliable estimation of effect. Four food-supplementation schemes for pregnant women in Colombia, the Gambia, Guatemala, and Taiwan (China) permitted such estimation (Lechtig and others 1975; Mora, Clement, Christiansen, Suescun, Wagner, and Herrera 1978; Mora, de Navarro, Clement, Wagner, de Paredes, and Herrera 1978; Lechtig and Klein 1979; Mora and others 1979; Herrera and others 1980; McDonald and others 1981; Delgado, Martorell, Brineman, and Klein 1982; Delgado, Valverde, Martorell, and Klein 1982; Overholt and others 1982; Mora 1983; Adair, Pollitt, and Mueller 1983, 1984; Prentice and others 1983; Adair and Pollitt 1985; Prentice and others 1987). The effect on dietary intake of supplementary food during pregnancy (detailed in table 18-6) was studied in relation to maternal weight gain, maternal activity, maternal body mass, and birth weight.[2]

Recent studies (Merchant, Martorell, and Haas 1990a, 1990b) of the nutritional stress of simultaneous pregnancy and lactation in poorly fed mothers show that mothers appear to absorb much of the deficit in energy by mobilizing their fat stores, and birth weight is little affected. Thus one might expect mothers more than their fetuses to benefit from the food supplementation. This was not the case. These studies showed little effect of supplemental food on maternal weight gain but did show a substantial improvement in mean birth weight,

Table 18-5. Causes and Interventions for Malnutrition

Causes	Contributing factors	Interventions	Activities
Inadequate intake of calories, protein, amino acids	Food (quantity and quality)	Resource transfer: supplementary foods	Food delivery to target individual or to family Feeding programs Nutrition rehabilitation
		Subsidies, transfer programs	Price subsidies Food stamps
		New foods	Weaning food preparation: processed and home preparation
		Fortification	Processing, marketing, and distribution Incentives (pricing)
		Agricultural production	Prices, incentives
	Income	Income generation	Income generation projects
	Knowledge	Nutrition education: information transfer, behavior change	Face-to-face (individuals and groups) Mass media
	Infant feeding	Promotion of breast-feeding	Training of health care personnel and mothers Restrictive legislation
	Time	Provision of child care	Support groups Day care centers
		Accessible cooking and water facilities	Better stoves Access to fuel Water projects
Nutrient losses, metabolic increases, and anorexia	Knowledge	Hygiene education	Face-to-face Mass media
	Water	Improved quality Improved quantity	Water projects, wells, pumps
	Feces	Latrines	Feces disposal
	Drugs	Drug administration	Distribution Prices
		Drug education	Training of health care personnel, individuals
	Vaccines	Immunization	Injections Distribution of vaccines
	Dehydration	Rehydration therapy: package or home remedy	Intravenous, nasogastric, oral (ORT)
	Medical care	Medical care	Medical care

Source: Authors.

which was greater the more malnourished the pregnant woman (table 18-7). Neither weight gain (Adair, Pollitt, and Mueller 1983; Adair and Pollitt 1985; Prentice and others 1987) nor measured activity patterns during pregnancy (Roberts 1982; Lawrence 1988) changed markedly in response to supplementation. Standardizing for the increase in total net caloric intake attributable to the supplement over the course of pregnancy (derived from values in table 18-6), we find that the improvements in birth weight per unit of increase in energy intake ranged from a high of 34 grams per 10,000 kilocalories in Colombia to a low of 14 grams and 8 grams per 10,000 kilocalories, for males and females, respectively, in Taiwan (China).

Because of the relation between infant mortality and birth weight, improving the caloric intake of malnourished pregnant women through food supplementation can result in a lower infant mortality rate. The difference in incidence of low birth weight attributable to the increase in energy intake reported

Table 18-6. Supplementation during Pregnancy

Location	Period of supplementation	Treatment group	Maternal anthropometry: Weight (kg)	Maternal anthropometry: Height (cm)	Maternal intake: Energy (kcal/day)	Maternal intake: Protein (g/day)	Supplement distributed: Energy (kcal/day)	Supplement distributed: Protein (g/day)	Net intake: Energy (kcal/day)	Net intake: Protein (g/day)
Bogotá, Colombia	Third trimester	Supplement	—	150 ± 5	1,646 ± 630[a]	37 ± 23[a]	856	38	133[b]	20[b]
		No supplement	—	150 ± 5	1,606 ± 665[a]	37 ± 20[a]	0	0	33[b]	2[b]
		Low maternal weight-for-height[a]								
		Supplement	—	—	1,589 ± 632[a,d]	35 ± 21[a,d]	856	38	334[b,e]	25[b,f]
		No supplement	—	—	1,589 ± 632[a,d]	35 ± 21[a,d]	0	0	29[b,e]	1[b,f]
		Full-term								
		Supplement	—	—	1,623 ± 635[a]	36 ± 19[a]	856	38	150[b]	9[b]
		No supplement	—	—	1,621 ± 655[a]	37 ± 23[a]	0	0	48[b]	1[b]
Taiwan (China)	Previous lactation and pregnancy	Supplement A	50 ± 5	155 ± 5	1,121[g]	37[g]	800	40	1,650[h]	64[h]
		Supplement B	49 ± 5	154 ± 5	1,197[g]	37[g]	80	6	1,206[h]	37[h]
Guatemala	Entire pregnancy	Atolé	48[d]	149 ± 5	1,473 ± 467[g]	42 ± 13[g]	163[i]	11.5[i]	1,580	48
		Fresco	48[d]	149 ± 5	1,411 ± 467[g]	42 ± 13[g]	59[i]	0[i]	1,492	42
Keneba, The Gambia	From sixteenth week	Postsupplement	50[d]	158[d]	—	—	1,300[j]	49[j]	1,898	—
		Presupplement	50[d]	158[d]	1,467	—	0	0	1,467	—
		Wet season								
		Postsupplement	50[d]	158[d]	—	—	1,500[j]	56[j]	1,838	—
		Presupplement	50[d]	158[d]	1,418	—	0	0	1,418	—

— Data not available.
a. In sixth month of pregnancy.
b. Difference between post- and presupplementation periods.
c. Less than 0.36 kg/cm.
d. For combined groups.
e. Significant difference between groups; $P < 0.005$.
f. Significant difference between groups; $P < 0.001$.
g. Home dietary intake; no initial dietary intake values reported.
h. Significant difference between groups; $P < 0.01$.
i. Content per 180 ml; offered ad libitum.
j. Maximum.

Source: Lechtig and others 1975; Mora, Clement, Christiansen, Suescun, Wagner, and Herrera 1978; Mora, de Navarro, Clement, Wagner, de Paredes, and Herrera 1978; Lechtig and Klein 1979; Mora and others 1979; Herrera and others 1980; McDonald and others 1981; Delgado, Martorell, Brineman, and Klein 1982; Delgado, Valverde, Martorell, Brineman, and Klein 1982; Overholt and others 1982; Mora 1983; Adair, Pollitt, and Mueller 1983, 1984; Prentice and others 1983; Adair and Pollitt 1985; Prentice and others 1987.

Table 18-7. Supplementation during Pregnancy: Outcome

Location	*Treatment group*	*Incidence of LBW*[a] *(percent)*	*Maternal weight gain (kg)*	*Mean birth weight*	*Mean birth weight per intake ($g/10^4$ kcal)*[b]
Bogotá, Colombia	Supplement	8.7	—	2,978 ± 377	34.1
	No supplement	11.0	—	2,927 ± 392	n.a.
	Low maternal weight-for-height				
	Supplement	—	—	3,014 ± 379[c]	55.4
	No supplement	—	—	2,833 ± 412[c]	n.a.
	Full-term				
	Supplement	—	4.2 ± 1.8[d,e]	3,003 ± 354[f]	35.4
	No supplement	—	3.5 ± 1.7[d,e]	2,940 ± 318[f]	n.a.
Taiwan (China)	Males				
	Supplement A	—	7.5 ± 2.8[g]	3,216 ± 348	13.8
	Supplement B	—	7.8 ± 2.5[g]	3,161 ± 364	n.a.
	Females				
	Supplement A	—	7.5 ± 2.8[g]	3,013 ± 411	8.0
	Supplement B	—	7.8 ± 2.5[g]	2,981 ± 321	n.a.
Guatemala	Atolé[h]	—	—	3,077 ± 334	21.0
	Fresco[i]	—	—	3,027 ± 461	n.a.
Keneba, The Gambia	Postsupplement	8.0[e]	—	2,891 ± 27[j,k]	16.0
	Presupplement	18.4[e]	—	2,882 ± 37[j,k]	n.a.
	Wet season				
	Postsupplement	7.5[l]	—	3,031 ± 32[e,j]	28.8
	Presupplement	23.7[l]	—	2,842 ± 48[e,j]	n.a.

— Data not available.
n.a. Not applicable.
a. Birth weight less than 2,500 g.
b. Calculated from the net intake per day times an estimate of the total number of days supplemented during pregnancy. In Guatemala, women did not start receiving supplement until they recognized that they were pregnant, so birth weight per input is likely to be a slight underestimate.
c. Significant difference between groups; $P < 0.01$.
d. Third trimester.
e. Significant difference between groups; $P < 0.005$.
f. Significant difference between groups; $P < 0.001$.
g. Total group.
h. Atolé is a food supplement high in energy and protein.
i. Fresco, which has a low content of energy and no protein, was used as a control.
j. Adjusted for sex, parity, and gestational age.
k. Significant difference between groups; $P < 0.05$.
l. Significant difference between groups; $P < 0.002$.
Source: Mora and others 1979; Herrera and others 1980; McDonald and others 1981; Delgado, Martorell, Brineman, and Klein 1982; Mora 1983; Adair, Pollitt, and Mueller 1984; Prentice and others 1983; Adair and Pollitt 1985; Prentice and others 1987.

in table 18-6 varied from 2.3 percentage points in Colombia, where the incidence of low birth weight in the unsupplemented group was 8.7 percent, to 10 percentage points in the Gambia, where the presupplementation incidence (averaged over all seasons) had been 18 percent.

The selection of subgroups for targeted interventions on the basis of characteristics of those who are known to respond rather than the selection of subgroups on the basis of characteristics associated with malnutrition is likely to be much more effective. The response in birth weight to maternal food supplementation is greater among chronically and acutely malnourished women, as well as those who smoke. In Colombia, the mean birth weight of infants of women whose weight-for-height was low and whose diet was supplemented was 181 grams more than their counterparts whose mothers received no supplements (Mora 1983); in the total group, the difference in birth weight between the infants of those whose diets were supplemented and those whose diets were unsupplemented was only 51 grams. In Taiwan (China), "tall and thin" women who were below the median weight and above the median height had larger birth weight in response to supplementation than "short and thin" subjects (Adair and Pollitt 1985). The better response in tall, thin women to supplementation emphasizes an irreversible detrimental effect of stunting in women and points to an additional advantage of preventing stunting during childhood. Women may also be more responsive to food supplementation during periods of seasonal food shortage, as illustrated by results from the Gambia, where the gain in birth weight per unit of supplementation was higher during the wet season, when food availability is low (table 18-7).

In the studies conducted in relatively well nourished populations, supplementation of the diets of smokers had a greater effect on birth weight than the supplementation of those of nonsmokers (Rush, Stein, and Susser 1980a, 1980b; Kennedy and Kotelchuck 1984). This effect may be of importance in developing countries as smoking among women increases. If the effect of smoking on birth weight is a result of carbon monoxide and not nicotine or cyanide compounds (Kramer 1987), it may also be relevant among women who are exposed to smoke from wood stoves in poorly ventilated houses.

Studies of food supplementation in lactating women have shown mixed results. A well-implemented trial showing no effect (Prentice and others 1980; Prentice, Roberts, and Prentice 1983) may still be confounded by secular trends. The only randomized double blind trial conducted to date (Gonzalez and others 1991) of food supplementation in lactating women who had no supplementation during pregnancy showed a clear-cut increase in breast milk in a group of chronically malnourished women. The increase was larger among the initially most malnourished. This study also showed that women whose diet was supplemented prolonged full breastfeeding. These findings have implications not only for maternal and infant nutrition but also for birth spacing, because full breastfeeding postpones the return of fecundability much more than does maternal malnutrition (Kurz and others 1990).

Results of a recent observational study in Brazil point to a "weanling dilemma" for infants of poorly nourished mothers in contaminated environments (Martines and others 1988). Growth faltered at about three to four months of age among solely breastfed infants of poorly nourished mothers, whereas solely breastfed infants of well-nourished mothers maintained normal growth at this age (Martines and others 1988). The provision of solid food to the infants of poorly nourished mothers did not appear to be a solution, because diarrhea and other infections resulting from contamination of the foods had an even worse effect on growth than the inadequacy of maternal milk production (Martines and others 1988). Thus, where environmental sanitation is poor, postponing the introduction of weaning foods beyond the optimal period for infants in sanitary environments is less detrimental to infant growth than is the introduction of contaminated foods at that time. The "weanling dilemma" might be solved by improving the nutrition of the malnourished mothers so that growth of their infants does not falter, or by providing uncontaminated foods to infants. Empirical studies, however, have as yet not shown that either of these strategies improve infant growth.

Several studies that were sufficiently well designed to make estimations of the effect of food supplements on the growth of children (Gopalan and others 1973; Martorell, Klein, and Delgado 1980; Mora and others 1981; Martorell, Habicht, and Klein 1982) are reviewed here. Improved dietary intake among children as a result of the provision of supplementary food (detailed in table 18-8) has the potential to be partitioned into different biological responses, such as growth, activity, and compensation for energy lost during illness, although most studies reported only anthropometric indicators of growth. Behavioral changes resulting from provision of energy (Chavez and Martinez 1975; Chavez, Martinez, and Yaschine 1975) may also improve cognitive development, but that will be discussed in the section on integrated interventions, because well-designed studies which have measured this effect have also provided behavior-modifying interventions to the child.

Supplementation of children's diets improved both their weight and height (table 18-9). The response in growth depended on the age of the child, which determined both the magnitude and kind of deficiency, whether in protein or calories. Provision of supplemental food remedied these deficiencies to a marked but still imperfect degree. Taking into account the duration of supplementation (derived from table 18-8), we estimate the height difference to vary from a high of 5.0 centimeters per 100,000 kilocalories ingested by Guatemalan females age thirty-six months to a low of 0.8 centimeters per 100,000 kilocalories ingested by Indian children age forty-eight months to sixty months. The weight difference per supplement ingested ranged from a high of 800 grams extra per 100,000 kilocalories, attained by male Guatemalan children at thirty-six months of age, to a low of 40 grams extra per 100,000 kilocalories, ingested by Colombian children during the interval between eighteen months and thirty-six months of age.[3]

The variability in response to food supplementation in these studies, particularly in weight, may be because of the differences in age groups supplemented, infant and child feeding practices, incidence of infectious diseases, and the duration of supplementation. The studies in Bogotá and Guatemala included the most complete data for examining the effects of supplementation on incremental growth at different ages. The differences in the resulting relative rates of growth in length and in weight between the supplemented and unsupplemented children were greatest between nine months and twelve months, during peak incidence and duration of diarrhea, followed by the weaning period from three to six months (Lutter and others 1990). Food supplementation also modified the negative effect of diarrhea on growth. Diarrhea was negatively related to growth in length in the unsupplemented group, but had no effect on length in the supplemented group (Lutter and others 1989). The effect of supplementation depended on the level of diarrheal disease, having a greater effect on length in those with the most diarrhea and no effect on children with low levels of diarrhea (Lutter and others 1989). Similarly, in Guatemala, in the villages provided with a protein and energy-enriched supplement, the effect of diarrhea on growth was attenuated (Martorell, Rivera, and Lutter 1988; Rivera, Martorell, and Lutter 1989).

Finally, children also responded differently to supplementation at different ages according to their body composition. In

Table 18-8. Supplementation to the Child

Location	Duration of supplementation	Treatment group	Age of child (months)	Home dietary intake[a]: Energy (kcal/day)	Home dietary intake[a]: Protein (g/day)	Total supplement distributed: Energy (kcal/day)	Total supplement distributed: Protein (g/day)	Net intake: Energy (kcal/day)	Net intake: Protein (g/day)
India	Fourteen months	Supplement	12–23[b]	700[b]	18[b]	310	3	310	3
		No supplement	12–23[b]	700[b]	18[b]	0	0	0	0
Bogotá, Colombia	From mother's last trimester to three years of age	Supplement	18	1,020 ± 706	24 ± 38	623	30.0	1,478 ± 711	58 ± 40
		No supplement	18	1,310 ± 445	36 ± 18	0	0	1,310 ± 445	36 ± 18
		Supplement	36	1,017 ± 373	24 ± 16	623	30.0	1,380 ± 453	48 ± 24
		No supplement	36	1,167 ± 476	27 ± 16	0	0	1,167 ± 476	27 ± 16
Guatemala	From mother's pregnancy to three years of age	Male							
		Atolé	15–36	785 ± 213	20 ± 6	163[c]	11.5[c]	941 ± 226	31 ± 8
		Fresco	15–36	814 ± 213	19 ± 6	59[c]	0[c]	840 ± 226	22 ± 8
		Female							
		Atolé	15–36	718 ± 213	20 ± 6	163	11.5	868 ± 226	21 ± 8
		Fresco	15–36	756 ± 213	19 ± 6	59	0	779 ± 226	8 ± 8

a. Home dietary intake values are likely to be an underestimate of the intake the population would normally consume, since some of the home diet is probably displaced by the supplement.
b. For entire population.
c. Per 180 ml, fed ad libitum.
Source: Gopalan and others 1973; Martorell, Klein, and Delgado 1980; Mora and others 1981; Martorell, Habicht, and Klein 1982.

Table 18-9. Supplementation to the Child: Outcome

			Initial measurements		*Final measurements*		*Increment*		*Outcome + Input* [b]	
Location	*Treatment group*	*Age of child (months)*	*Stature*[a] *(cm)*	*Weight (kg)*	*Stature*[a] *(cm)*	*Weight (kg)*	*Stature*[a] *(cm)*	*Weight (kg)*	*Stature*[a] *(cm/10^{5}kcal)*	*Weight (kg/10^{5}kcal)*
India	Supplement	12–24	—	—	—	—	9.3[c]	2.35[c]	2.1	0.49
	No supplement	12–24	—	—	—	—	6.5[c]	1.71[c]	n.a.	n.a.
	Supplement	24–36	—	—	—	—	9.5[c]	2.34[c]	1.3	0.48
	No supplement	24–36	—	—	—	—	7.8[c]	1.71[c]	n.a.	n.a.
	Supplement	36–48	—	—	—	—	9.1[c]	2.04[d]	1.3	0.35
	No supplement	36–48	—	—	—	—	7.4[c]	1.58[d]	n.a.	n.a.
	Supplement	48–60	—	—	—	—	8.4[e]	1.86[a]	0.8	0.37
	No supplement	48–60	—	—	—	—	7.3[e]	1.38	n.a.	n.a.
Bogotá, Colombia	Supplement	18–36	75.1 ± 2.7	9.48 ± 1.09	87.5 ± 3.4[f]	12.35 ± 1.40[e]	12.4	2.87	1.5	0.05
	No supplement	18–36	73.5 ± 3.1	9.06 ± 1.04	85.3 ± 4.4[f]	11.88 ± 1.19[e]	11.8	2.82	n.a.	n.a.
Guatemala	Male									
	Atolé	36	84.3 ± 4[g]	11.6 ± 1.3[g]	86.9 ± 3.9[c]	12.4 ± 1.3[c]	—	—	2.8	0.79
	Fresco	36	84.3 ± 4[g]	11.6 ± 1.3[g]	85.1 ± 3.9[c]	11.9 ± 1.3[c]	—	—	n.a.	n.a.
	Female									
	Atolé	36	84.3 ± 4[g]	11.6 ± 1.3[g]	85.9 ± 3.9[c]	11.9 ± 1.3[c]	—	—	5.0	0.70
	Fresco	36	84.3 ± 4[g]	11.6 ± 1.3[g]	83.1 ± 3.9[c]	10.8 ± 1.3[c]	—	—	n.a.	n.a.

— Data not available.
n.a. Not applicable.
a. Some studies reported recumbent length, and others reported standing height. The use of length or height makes no difference to the net outcome, because it is determined by the difference between measurements.
b. Input is calculated as the kilocalories of supplement ingested per day dimes the duration of supplementation. In Colombia, the intake was the average of the intakes at eighteen and thirty-six months. In Guatemala, where infants also receive breast milk, the amount of supplement is likely to be less; the duration of supplementation therefore was considered to be the period between twelve and thirty-six months.
c. Significant difference between groups; $P < 0.001$.
d. Significant difference between groups; $P < 0.01$.
e. Significant difference between groups; $P < 0.05$.
f. Significant difference between groups; $P < 0.005$.
g. Total population.
Sources: Gopalan and others 1973; Martorell, Klein, and Delgado 1980; Mora and others 1981.

Guatemala, children of high weight-for-length at six months (Rothe, Rasmussen, and Habicht 1988) had higher weight gain, and at eighteen months of age (Marks 1989) had better linear growth in response to supplementation than children of low weight-for-length. At thirty months of age, this response was reversed; children of low weight-for-length responded with better linear growth (Marks 1989). The better linear growth of fatter children at younger ages in response to supplementation could be explained by two potential mechanisms: (a) protein is more limiting in younger children, or (b) younger children need to build up fat reserves before they can respond with better linear growth. Further research is needed to test either of these hypotheses.

FOOD SUBSIDIES AND TRANSFERS. Food price policy, food subsidies, and food-related transfer programs influence the ability of households to acquire food (Pinstrup-Andersen 1985). Evidence from studies in more than a dozen countries shows that food price subsidies and food stamp programs have increased incomes and improved food consumption among the poor, particularly but not exclusively in urban areas (Pinstrup-Andersen 1988). In many of the countries studied, the transfers from such programs contributed 15 to 25 percent of total income of the poorest 10 to 20 percent of the population reached. In general, each 1 percent increase in the income of the poor results in a 0.2 to 0.4 percent increase in household energy consumption and a somewhat higher percentage increase in the consumption of protein. Thus, although the effect varies among countries and population groups, food subsidy programs that add 20 percent to the purchasing power of the poor can be expected to increase their energy consumption by 4 to 8 percent. The effect will be higher among the poorest and most destitute.

The extent to which increases in household food consumption lead to improved nutritional status depends on the degree to which malnourished household members share in the increase and on the relative importance of food deficiency and infectious diseases. If food deficiency is not the only limiting constraint to improved nutrition, increased food consumption may have little or no effect. In Egypt, for example, existing food subsidies contributed to high levels of food consumption even among the poor. Malnutrition was still significant, however, because the effect of poor sanitation and diarrhea on growth were not effectively addressed (Alderman and Von Braun 1984; Alderman, Von Braun, and Sakr 1982).

Empirical evidence on the effect of food subsidies and price policies on the nutritional status of preschool children is limited. Kumar (1979) found that the weight-for-age of children in Kerala, India, would fall by 8 percent if the existing subsidized food ration scheme was discontinued. Similarly, food subsidies contributed significantly to increases in energy and protein intake and weight-for-age of preschool children in the Philippines (Garcia and Pinstrup-Andersen 1987).

WEANING FOODS. The risk of PEM and PEM-related mortality is particularly high during the weaning period. Programs to improve weaning practices frequently involve the promotion of improved weaning food, whether made from local foods or commercially premixed (Gibbons and Griffiths 1984). Researchers who studied projects promoting weaning foods in Haiti (Berggren 1981) and Burkina Faso (Zeitlin and Formación 1981) found strong positive effects on the nutritional status of children. The affordability of weaning foods is an important consideration, and emphasis should be placed on locally available foods. Successes from recent integrated interventions may reflect a positive effect of improved weaning foods. Attempts to isolate the nutrition effect of each of a number of interventions, such as weaning foods, that form part of an integrated program may not be warranted because the effect of one is heavily influenced by the presence of others.

FORTIFICATION. Although fortification may be effective in alleviating deficiencies in micronutrients, fortification to alleviate PEM has not generally been successful. Amino-acid fortification has been tried in a number of populations. In many cases, however, little or no effect was detected, partly because the programs were not designed in such a way that they could be evaluated and partly because the staple foods on which fortification was tested—for example, wheat in Tunisia and rice in Thailand (NAS 1988)—were less likely to lead to a critical imbalance in amino acids than other staples, such as corn, cassava, or sweet potatoes. Thus, the additional protein provided was most likely converted to energy.

AGRICULTURAL PRODUCTION. Agricultural programs and policies may have important nutrition implications through their effect on incomes of the rural poor, food prices to be paid by poor consumers, time allocation by members of poor households, energy and protein expenditure, infectious diseases, and food consumption by high-risk individuals (Mebrahtu, Pelletier, and Pinstrup-Andersen, in press). Positive nutrition effects may be increased and negative ones alleviated by including in the design of such programs and policies consideration of how each of these six factors will be affected.

Agricultural research and technology have contributed to large increases in food production in many developing countries during the last twenty-five years, most notably in Asia and Latin America (Pinstrup-Andersen 1982). These increases have resulted in higher incomes for farmers and landless workers as well as lower food prices for consumers. Low-income farm families with members at risk of PEM have participated in these income gains, and the lower food prices have been particularly important for poor consumers, becausc they spend a large share of their income on food (Pinstrup-Andersen and Hazell 1985). Although evidence from other sources shows that incomes and food prices are closely associated with the nutritional status of household members, implying a positive nutrition effect of agricultural research and technology, no studies have been done to establish the link directly.

The authors of recent studies of projects to increase the commercial agricultural production by small farmers in the Gambia, Guatemala, India, Kenya, the Philippines, and

Rwanda (Alderman 1987; Kennedy and Cogill 1987; Von Braun, Hotchkiss, and Immink 1989; Von Braun, Puetz, and Webb 1989; Bouis and Haddad 1990; and Von Braun, de Haen, and Blanken, 1991) found strong positive effects on farm incomes and family food consumption. The effect on the nutritional status of preschool children was also positive but small, in some cases statistically insignificant. The results of these studies demonstrate that agricultural projects may be powerful in alleviating the household resource constraints to good nutrition but may have little effect on nutrition unless other constraints, such as infectious diseases and adverse household behavior, are removed at the same time.

INCOME GENERATION. Protein-energy malnutrition is closely associated with poverty, and increased household incomes are important for improved nutrition. Still, as illustrated above, additional income is not always sufficient for its elimination. There are several reasons for this. In the short run, additional income is likely to increase access to food but may have little effect on general sanitary conditions, knowledge, and access to and use of health care. In the absence of good sanitation and health care, additional food may have little nutritional effect. In the longer run, increased income is likely to improve living conditions, reduce health risks, and improve nutrition, particularly if accompanied by better information and behavioral changes. In the meantime, increased access to food may have a significant effect on nutrition only if primary health care and programs to modify household behavior and improve sanitary conditions and access to more and cleaner water are introduced as well.

Another reason why income increases may not be as effective as expected is that households may be unaware that a nutrition problem exists, they may lack knowledge and information about how best to use additional income for nutritional improvements, or they may be faced with extreme scarcity of other basic necessities which compete with nutrition for household resources. In such cases, growth monitoring or nutrition education may be needed along with efforts to assist households in meeting other basic needs.

The nutrition effect of income increases may also be less than expected because women allocate more time to income generation and less to child care, cooking, and other nutrition-related activities. In such cases, programs to increase the productivity of women's time within or outside the household are needed. Finally, intrahousehold income control may be in the hands of household members who place low priority on nutrition improvement.

NUTRITION EDUCATION. Several researchers have completed reviews of the effect of nutrition education programs during the last few years, including Whitehead (1973), Zeitlin and Formación (1981), Hornik (1985), Johnson and Johnson (1985), and Cerqueira and Olson (in press). The general conclusion from these reviews is that well-designed and well-implemented nutrition education programs can bring about behavioral changes that contribute to improved nutrition at relatively low cost. In low-income households, such programs are most likely to be successful when the behavioral changes can be accomplished without additional resources (Hornik 1985). The interaction between resource availability at the household level and the opportunity for nutritional improvement through behavioral changes is an important consideration in the design of nutrition intervention programs. In very poor households, constraints on resources may prohibit behavioral changes and thereby limit the effectiveness of nutritional education.

Cerqueira and Olson (in press) argue that lack of success in many past nutrition education programs is due in large part to the influence of the traditional medical model, that is, curative rather than preventive. Recent participatory models with or without the use of mass media have contributed to significant nutrition improvements in several countries, including Indonesia (Zeitlin and others 1984), the Dominican Republic (USAID 1988), Tanzania (UNICEF 1988), and India (Shekar 1991). In most of these cases growth monitoring played an important role as a source of information for the education effort, and in some but not all of these programs nutrition education was closely integrated with other interventions (Cerqueira and Olson, in press). Thus, nutrition education offers great promise for nutritional improvements through behavioral changes when (a) the design and implementation is based on a thorough understanding of the environment within which the intended beneficiaries live and of the constraints they face, including those that limit behavioral changes; (b) the target community is intimately involved in the design and implementation of the complete set of interventions; and (c) household resource constraints are alleviated.

PROMOTION OF BREASTFEEDING. Breastfeeding contributes significantly to reduced infections and malnutrition in infants and children. Promotion of breastfeeding has been successful in increasing the rate of breastfeeding (Feachem and Koblinsky 1984). Maternal behavioral response to breastfeeding promotion varies according to socioeconomic characteristics (Hardy and others 1982). Training and education of health professionals in the advantages of breastfeeding and in techniques to help mothers breastfeed have been successful in a number of countries (Huffman and Steel, in press), including Indonesia, Thailand, Panama, and the United States. Appropriate hospital delivery practices, community support groups, and arrangements permitting mother and infant to stay together while in the hospital have proved effective in increasing breastfeeding rates and the ways breastfeeding is practiced in several countries (Huffman and Steel, in press).

Integrated Interventions to Improve Dietary Intake

Synergism among interventions may result in integrated strategies' having effects different from the sum of the effect of each of the individual interventions. Substitution and complementarity between and among interventions often play an important role in determining the total effect of a set of interventions. On the basis of a review of nutrition education programs in developing countries, Hornik (1985) concludes that nutrition education generally has been most successful when combined with increased household resources. Complementarity between nutrition education and food supplementation has been demonstrated by Gilmore and others (1980) in Morocco, and Garcia and Pinstrup-Andersen (1987) found complementarity between nutrition education and food price subsidies in the Philippines. Developmental education to influence maternal knowledge, behavior, and time spent with the child appears to increase the effect of food on growth and cognitive development. Home visits by fieldworkers to stimulate learning and development and positive caretaker-child interaction among families participating in the Bogotá Nutrition and Child Development Project (Herrera and others 1980) resulted in a growth in height of 1.3 centimeters more in children in the supplemented group who had received stimulation than in those who had not (Lutter 1987). This effect on height-for-age persisted at six years of age (Super and others 1989).

The main effect of stimulation was stronger than the main effect of supplementation in the Bogotá study for almost all the indexes of cognitive development tested (Cremer and others 1977). The highly significant interaction of supplementation and stimulation (Cremer and others 1977), points to the synergism of food and behavioral stimulation interventions. Similarly, behavioral stimulation had a much larger effect on cognitive development than dietary supplementation in children in Cali, Colombia (McKay and Sinisterra 1974, McKay and others 1978), although these results may be biased because participants were explicitly told the nature and the expected outcome of the study. Stimulation of severely malnourished children in a hospital also had similar effects (Grantham-McGregor and others 1979; Grantham-McGregor, Stewart, and Schofield 1980; Grantham-McGregor, Schofield, and Harris 1983).

Integration of efforts to improve nutrition and health in small-scale projects has positively affected nutrition and mortality (Gwatkin, Wilcox, and Wray 1980; Lamptey and Sai 1985). Two recent integrated projects—the Tamil Nadu Integrated Nutrition Program in India and the Iringa Project in Tanzania—have been particularly successful in reducing child malnutrition. Thus, TINP is estimated to have reduced the prevalence of severe malnutrition among children six months to thirty-six months old by one-third to one-half the prevalence that existed at the beginning of the project. The continued effect of TINP and another nutrition project in the region is estimated to be a 50 percent reduction of the prevalence of malnutrition among children less than five years old (World Bank 1990). An equally impressive result was obtained by the Iringa Project, which is estimated to have reduced severe and moderate malnutrition in the project area by 70 and 32 percent, respectively (UNICEF 1989; Yambi and others 1989).

Case Management of Severe Malnutrition

Most of the interventions previously described can be considered preventive because a diagnosis of severe malnutrition need not be among the criteria for receiving treatment. Nutritional status may be used to target interventions such as food supplementation, but the goal of the selection procedures is to prevent severe PEM and its consequences rather than to provide rehabilitation once it occurs. Severely malnourished children are commonly treated in two types of facilities: hospitals and nutrition rehabilitation (or mothercraft) centers.

In hospitals generally, the case-fatality rate of severe malnutrition has been reported to be approximately 25 percent (McLaren and others 1969; Cook 1971). Most studies of hospital-based case management of severe PEM on which these rates are based were conducted more than twenty years ago. In the interim, new methods of treatment and feeding schedules with better potential to reduce this high case-fatality rate have been developed (Waterlow and others 1978; WHO 1981). The effectiveness of these innovations will depend on adequate training and sufficient time and personnel to administer the frequent feedings required for rehabilitation. Follow-up upon release from the hospital is necessary to avoid relapse. Reported case-fatality rates ranged from 15 to 37 percent, but they dropped to nearly zero in the twelve-month period if "conscientious efforts were made for follow-up" (Cutting 1983, p. 121).[4]

Nutrition rehabilitation centers vary from those incorporated into a highly technical medical infrastructure to those completely separate from medical facilities (Beaudry-Darisme and Latham 1973). The case-fatality rates in a four-month period ranged from 0 to 6 percent (Beghin and Viteri 1973).

The effect of length of attendance at rehabilitation centers on nutritional status was retrospectively examined in two different countries, with equivocal findings (Beaudry-Darisme and Latham 1973). In Haiti, improvement in the median weight-for-age by the time of discharge and ability to maintain it one year after discharge were significantly greater in those who attended the centers for two months than for those who attended for one month. The mean percentage of Guatemalan children who attained and maintained the median weight-for-age was the same regardless of length of attendance.

Still, the above outcomes are all the result of poor planning or management rather than intrinsic biological constraints on recovery. In a well-managed trial in Guatemala, all malnourished children recovered when they received 10 percent or more of their recommended energy intake from food supplementation (Rivera, Habicht, and Robson, in press).

Questions yet to be resolved are what referral criteria would be most appropriate and under what conditions are the two types of facilities most useful to rehabilitate severely malnourished children when preventive efforts fail. A comparison of the relative effectiveness of hospitals and nutritional rehabilitation centers indicated that nutrition rehabilitation centers were more effective in curing malnutrition, although the outcome measure was not specified (Cook 1971). The criteria for hospital admission and prognosis may have been different for the two types of facilities, however, because hospitals usually deal with severe malnutrition, whereas rehabilitation centers handle less severe cases. This type of comparison is not useful in determining clinical criteria for referral of children from nutritional rehabilitation centers to hospitals. Perhaps because the costs are so high, the further study of criteria for referral has been grossly neglected.

Cost, Cost-Effectiveness, and Benefit-Cost

While direct costs of nutrition intervention are frequently reported, total costs and benefits are difficult to estimate. This section provides rough estimates only.

FOOD SUPPLEMENTATION. As shown in table 18-10, the cost of food supplementation varies among programs. Such variation provides little indication of cost-effectiveness, however, because the programs vary in nature and presumably in nutrition effect. As expected, the cost is lowest for food subsidy schemes that depend on the market for food distribution and include no other program components, such as those in the Philippines, Sri Lanka, and Egypt, and highest for integrated programs implemented by the public sector, such as the Tamil Nadu and the Colombian programs.

These cost estimates provide an input into assessments of cost-effectiveness. On the basis of the estimates presented in table 18-10, it seems reasonable to assume a cost of \$0.20 per 1,000 calories transferred in programs that provide no other services. This rough overall estimate is used in an assessment of cost-effectiveness and a benefit-cost analysis presented below.

Two cost-effectiveness analyses are reported here. Both assess the cost of averting a child death by means of food supplementation. The first, which relates to food supplementation for preschool children, is based on the relation between food supplementation and child growth, shown in table 18-9, and the relation between the weight-for-age of preschool children and their rate of mortality estimated for five countries and synthesized by Pelletier (1991). The result from the assessment, which should be interpreted as rough magnitudes rather than exact figures because of the assumptions made, is that the cost of averting a death is \$1,942, which converts to a cost of \$62.65 per disability-adjusted life-year (DALY). The second refers to food supplementation of pregnant women and is based on the relation between food supplementation and birth weight shown in table 18-7 and the relation between birth weight and infant mortality shown by Walsh and others (in press). If we assume a gain of 300 grams in the birth weight per 100,000 calories transferred to pregnant women (table 18-7) and a decrease of 9 per 1,000 in the child mortality rate for each 100-gram increase in the birth weight (approximated from Walsh and others, in press), the cost per child death averted is estimated at \$733.00, or \$23.65 per DALY. The assumptions made and the methodology used in this assessment are explained in appendix 18A.

The benefit-cost analysis is based on the elasticity of labor productivity of 1.38 with respect to height of the worker, reported by Haddad and Bouis (1990) and discussed in an earlier section of this chapter, and the estimated relation between food supplementation and height of preschool children (table 18-9). Estimates of the latter vary from 0.8 to 5.0 centimeters per 100,000 calories transferred. For this analysis, an estimate of 2.0 is used. This corresponds to the finding for Indian children age one to two years (table 18-9). The sensitivity of the result to the choice of estimate is tested by using estimates of 1.0 and 3.0 centimeters per 100,000 calories transferred. As above, a cost of \$0.20 per 1,000 calories transferred is assumed. The cost associated with an increase in height of 1.0 centimeter is then the cost of 50,000 calories, or \$10.00. Under the assumptions of a daily current wage of \$2.50

Table 18-10. Cost of Food Transfers in Various Types of Programs

Program type	*Country*	*Year*	*Cost per 1,000 calories delivered (U.S. dollars)*	*Source*
Food subsidy	Brazil	1980	0.30	Berg 1987
Food subsidy	Colombia	1981	0.79	Berg 1987
Food subsidy	Egypt	1982	0.18	Alderman and Von Braun 1984; Kennedy and Alderman 1987
Food subsidy	Mexico	1982	0.42	Kennedy, Overholt, and Haddral 1984
Food subsidy	Philippines	1984	0.09	Garcia 1988
Food subsidy	Sri Lanka	1982	0.10	Edirisinghe 1987
MCH and feeding	Bolivia	1988	0.12	World Bank 1989
MCH and feeding	Brazil	1980	0.53	Berg 1987
MCH and feeding	Colombia	1982	0.38	Anderson and others 1981; Kennedy and Alderman 1987
MCH and feeding	Costa Rica	1982	0.60	Anderson and others 1981; Kennedy and Alderman 1987
MCH and feeding	Dominican Republic	1982	0.20	Anderson and others 1981; Kennedy and Alderman 1987
MCH and feeding	Ecuador	1988	0.21	World Bank 1989
MCH and feeding	Guatemala	1988	0.33	World Bank 1989
MCH and feeding	Honduras	1988	0.36	World Bank 1989
MCH and feeding	India (Tamil Nadu)	1985	0.69	Berg 1987
MCH and feeding	India	1982	0.20	Anderson and others 1981; Kennedy and Alderman 1987
MCH and feeding	Pakistan	1982	0.38	Anderson and others 1981; Kennedy and Alderman 1987
MCH and feeding	Paraguay	1988	0.90	World Bank 1989
MCH and feeding	Peru	1988	0.32	World Bank 1989
MCH and feeding	Uruguay	1988	0.24	World Bank 1989

Source: See last column.

and 300 working days per year, the annual current benefit is estimated at $6.45. Still, these benefits will begin only after the child enters the labor market, for example, at the age of eighteen years. Assuming a 2 percent annual rate of increase in the real wage, we find that the wage rate will have increased to $3.43 per day, or $1,030 per year, for the year the person enters the labor market. Thus, an investment of $10.00 in a child age six months to eighteen months will generate an income stream beginning sixteen years later and continuing for the duration of the productive life of the worker, say, until age fifty-five. This annual income stream will begin with $8.84 at age eighteen and end with $18.06 at age fifty-five. At a real discount rate of 3 percent, the present value of such an income stream is estimated to be $174.00, which, compared with the initial investment of $10.00 yields a benefit-cost ratio of 17.4. This is above most other investments made by the public sector. Reducing the effect of food supplementation from 2.0 centimeters to 1.0 centimeter per 100,000 calories resulted in a benefit-cost ratio of 8.7, whereas an increase to 3.0 was associated with a benefit-cost ratio of 26. Thus, even at the lower estimate of the effect of food supplementation on height, the return on investment in the growth of preschool children through food supplementation is high. The methodology used is presented in appendix 18A.

Estimates by Selowsky and Taylor (1973) for Chile and by Selowsky (1981) for Colombia also suggest high economic returns to government programs to improve child nutrition. In another study in Chile, Torche (1981) estimated that the economic return from a food supplementation program exceeded the discount rate of 17 percent usually applied to determine the economic viability of investment projects in the government sector. Additional studies of this nature are urgently needed to provide evidence of the economic return from nutritional improvements compared with the economic return from alternative investment and to increase the understanding of how to design nutrition interventions with high economic payoff.

NUTRITION EDUCATION. There is little reliable quantitative evidence on the cost-effectiveness of nutrition education. It may be difficult or impossible to isolate the effect of nutrition education when such education is an integral part of an intervention program. In such cases it may make more sense to evaluate the complete program, as discussed in the next section.

Two recent nutrition education programs provide information on costs and cost-effectiveness. Both are based on the social marketing strategy and both have been effective in improving nutrition. In Indonesia, the cost was $3.90 for each participant and $9.80 for each child whose nutrition was improved. In the Dominican Republic, the Applied Nutrition Education Program included about 9,000 children and cost about $23.00 per child annually. The prevalence of malnutrition, defined as weight-for-age below 75 percent of standard, decreased from 12.2 to 6.9 percent in a two-year period (1984–86). The cost per child removed from malnutrition was estimated at about $500.00 (USAID 1988). One reason for this relatively high cost estimate is that, although severely malnourished children were most closely monitored, program resources were provided to all children, of which only 12 percent were classified as malnourished at the start of the program. If the program could be targeted to the malnourished only, the cost would be reduced considerably without a reduction in the effect as measured. Alternatively, the cost-effectiveness is likely to be higher in populations with a higher prevalence of malnutrition. Furthermore, only benefits associated with the movement of children from below to above the cutoff of 75 percent of standard were considered, and nutritional improvements occurring within each of the two groups were ignored.

INTEGRATED PROGRAMS. Several recent integrated health and nutrition programs, including the Tamil Nadu Integrated Nutrition Program and the joint WHO/UNICEF Nutrition Support Program in Iringa, Tanzania, have been successful in significantly reducing PEM. The cost of removing a child from moderate and severe malnutrition was estimated to be $33 in Tamil Nadu (Ho 1985) and $46 in Iringa (estimated on the basis of data in UNICEF 1988). Using the methodology reported in the appendix, we estimated the cost per averted child death in Iringa to be $2,560, corresponding to a cost per DALY of $82.

COSTS OF CASE MANAGEMENT. The costs of case management of moderate to severe protein-energy malnutrition are considerably higher than the costs of prevention. Beaudry-Darisme and Latham (1973) compared the costs of rehabilitation centers in two different countries using standardized food and salary costs. The mean cost per child with a positive change in weight-for-age above the control was $605 in Haiti and $2,672 in Guatemala and was even higher for the decreased incidence of severe PEM above the control group at $3,627 in Haiti and $5,344 in Guatemala. In a comparative review of rehabilitation centers and hospitals, costs for the period of recuperation varied from $46 to $54 in Guatemala to $120 in Costa Rica in rehabilitation centers (Beghin and Viteri 1973). In urban Uganda the cost of recuperation was $78 in the recuperation center and $120.00 in the hospital (Beghin and Viteri 1973). In a study of six Latin American countries, the cost per bed-day at a hospital ranged from 4.5 to 18 times the cost per child per day at a rehabilitation center (Beghin 1970). Still, the severity of the PEM, the criteria employed for referral, and the duration of recovery, among other factors, could account for some of the difference in cost. Costs varied from $117.60 for inpatient hospital treatment for kwashiorkor for two weeks to $77.00 for a six-week inpatient stay that included educating the mother.

Strategies and Priorities

An effective strategy must identify and combine programs and policies that are likely to have the greatest sustained effect on the nutritional status of a particular population group or groups per unit of resources spent. The design of such a strategy is difficult because of strong synergisms, such as those between food intake and infectious diseases and between purchasing power and nutrition knowledge. These synergisms imply that the effect of changes in one factor may be slight unless other factors are changed simultaneously. Furthermore, because the nature, causes, and relative rewards of particular interventions vary among population groups, across countries, and over time, the strategy must be tailored to a particular set of circumstances. No one strategy is likely to be optimal for all population groups.

A national strategy to alleviate PEM should consider direct nutrition interventions, such as food supplementation and nutrition education; indirect interventions, such as programs to improve primary health care, sanitation, and water availability; and broader policies and programs, such as those involving price, income, credit, interest rate, and employment policies and those influencing asset ownership and user rights. Such broader policies are likely to exercise powerful influences on the nutritional status of the poor, even though they may not be explicitly addressed to nutritional concerns. Their nutrition effects—positive or negative—should not be ignored. This is particularly important because poverty, with its associated unsanitary living conditions and lack of access to sufficient food, health care, and information, is clearly the overwhelming determinant of PEM. As mentioned earlier, however, policies and programs with the sole goal of increasing incomes have not been as effective in alleviating malnutrition in the short run as expected.

The choice, design, and implementation of nutrition intervention programs should be made within the context of existing policies and expected changes in them, because specific policies benefit some groups of the poor and hurt others, thereby changing the needs and the appropriate target groups for nutrition programs. The most appropriate program choice, design, and implementation strategy will depend on existing economic policies as well as opportunities for policy change.

The specific strategy and related programs and policies must be tailored to each location and time period. Ideally, the most appropriate government support will be identified through effective participation by communities and target households in problem diagnosis, program implementation, and monitoring. With or without such participation, however, the choice, design, and implementation of nutrition intervention programs should be preceded by (a) identification of the target groups, assessment of the constraints to good nutrition with which they are faced, an assessment of their food acquisition and allocation and health-seeking behavior, and identification of opportunities for nutrition improvement; (b) assessment of institutional and administrative capabilities for program implementation; and (c) identification of sources of financing. Two vehicles for the generation of the relevant information—growth monitoring and nutritional surveillance—have shown great promise, not only for information generation, but also as mechanisms with which to identify, coordinate, and integrate interventions and policies into an effective strategy.

Growth monitoring by itself is not an intervention; rather it is a tool to coordinate appropriate interventions to promote growth in an individual child. Most of the successful integrated programs mentioned earlier include growth monitoring as a tool to integrate intervention activities. From the success of these programs it appears that growth monitoring and promotion can be an important instrument in an integrated strategy. Furthermore, the cost of adding growth monitoring to nutrition intervention programs is small (Griffiths 1985).

In their review of the early attempts at growth monitoring, Gopalan and Chatterjee (1984) came to the conclusion that much of the failure to achieve the promised potential of growth monitoring was due to the difficulty of interpreting the growth curve and the consequent lack of appropriate follow-up action. The Applied Nutrition Education Program in the Dominican Republic among others has demonstrated that training workers to implement specific activities to address specific patterns on the growth chart can be successful (USAID 1988). This is, however, but one of the constraints to be overcome to make growth monitoring successful (Ruel, in press).

Just as growth monitoring can be used to integrate health and nutritional interventions at the level of the individual, so nutritional surveillance can be used to plan and implement interventions in populations and coordinate and integrate these interventions to make them more effective and less costly (Mason and others 1984; Tucker and others 1989). Like growth monitoring, nutritional surveillance does not by itself prevent or cure malnutrition. Instead it provides the relevant information for the choice, design, and correct timing, synchronization, and concatenation of effective interventions. Because the relation between information and interventions effective for the population level is much less clear than it is between information and growth monitoring at the individual level, it is not surprising that no useful evaluations of effect have been done on nutritional surveillance. In the absence of such evaluations no firm conclusions can be drawn regarding the nutrition effects of nutritional surveillance. The relatively narrow form in which nutritional surveillance efforts have been operationalized in the past, however, suggests that any positive effects which have taken place are far short of the potential (Pelletier, in press). As illustrated by the willingness of the private sector to pay for market information, decisionmakers value relevant information. Information plays an important role in guiding government decisions related to food and nutrition (Alderman, in press). Thus, nutrition surveillance activities that make relevant and timely information available to decisionmakers is likely to result in better interventions. Because the cost of nutritional surveillance is such a small fraction of the cost of the interventions, the potential cost of wrong decisions, and the cost of maintaining the capability of intervening in crises that the generation of the type of information provided by effective nutrition surveillance should be encouraged.

The interaction between interventions and the socioeconomic and cultural environment within which they are introduced as well as the interaction among types of interventions and the synergism among factors influencing nutrition are of paramount importance in designing the strategy. This implies that integrated or concurrent interventions are more likely to be successful than single ones. Still, integrated interventions require institutional and administrative capabilities and infrastructure that are frequently in short supply.

In countries in which the necessary capabilities and infrastructure are available or can be developed as part of the program, integrated health and nutrition programs combined with favorable government policies offer great promise. Each program should be tailored to the particular circumstances but a combination of growth monitoring; nutrition education that emphasizes breastfeeding, child spacing, and weaning practices; financial and technical assistance for the production and distribution of weaning food; distribution of food stamps to participating households; and overall primary health care may form the core of most programs or part of the menu of options for consideration. Active community and target group participation in various aspects of program design and implementation is important for long-term sustainability, and separate but related efforts to assist the target groups in strengthening their income-generating capacity are needed to reduce the need for future outside financial support.

In countries in which the institutional and administrative capabilities and infrastructure are weak, less complex programs should be pursued. For example, in areas that have health posts, if insufficient food intake is a constraint to good nutrition, the distribution of food stamps to low-income mothers who bring their preschool children to the posts should be considered. Such a strategy was successful in urban and rural areas of Colombia and in both remote and less remote rural areas of the Philippines (Garcia and Pinstrup-Andersen 1987). Using food stamps instead of the more traditional food supplementation relieves the health system of physically distributing the food, a job for which it is not well equipped, without removing the food-related incentive for coming to the health post.

Rather than repeating the many other examples of appropriate interventions already discussed, we will only suggest that the introduction of any such intervention in a particular community should be preceded by a sound assessment of the situation and that the intended beneficiaries should participate in that assessment.

It should be stressed that attempts to set up large-scale nutrition programs that exceed the institutional and administrative capabilities have failed in the past and will fail if tried again. Instead, emphasis should be on strengthening these capabilities, including training at all levels and the building of nationwide primary health care systems, which may become the conduits for integrated nutrition and health programs. Such linkage will be successful only if nutrition is given a more prominent role in primary health care. At the same time, nutritional improvements should be pursued through policies and programs that require less administrative and institutional capabilities and infrastructure, such as price, income, and employment policies; credit and technical assistance to low-income people; basic training and education; and small-scale intervention programs. Such programs may be very cost-effective if designed by and for the community target groups with outside support.

In view of the above, high priority should be placed on strengthening the capacity of households, communities, and government agencies to assess the nutrition situation, to diagnose the problem, to identify the critical constraints to good nutrition, and to design, implement, and monitor strategies most appropriate for a particular situation. Priority should also be placed on making available to program designers and implementors information and technologies needed to ensure success in such strategies.

International assistance to reduce PEM should focus on the strengthening of this capacity through a combination of training, technical assistance, research, technology transfer, and financial support to cover program costs. The nature of each of these activities and the correct combination needs to be defined for each country and community. The overriding priority of international aid agencies and national governments should be to ensure that each community and each country is capable of defining, implementing, and obtaining financing for the most appropriate strategy and associated policies and programs. That—and not a specific technology or intervention—is the magic bullet to be applied across countries and communities.

In support of these priorities for action there is a need for operationally relevant research on a number of topics. First, a better understanding is urgently needed of how to make more effective the generation of useful information to support decisions by mothers, communities, and government agencies. For this purpose, research is needed to determine (a) how best to generate such information, for example, various formulations of growth monitoring or alternative sources of information for mothers and cost-effectiveness of various methods of nutrition surveillance for communities and government agencies; (b) how best to integrate information generation with the design and implementation of interventions and broader policies and programs; and (c) how best to analyze, interpret, and make available information, including the most appropriate institutional arrangements.

Second, there is an urgent need for sound evaluations of the nutritional effect of various formulations of integrated nutrition programs; of how such effect is influenced by the socioeconomic and cultural environments, including existing nutrition-related policies; and of how information from such evaluation can be generalized for use in the guidance of programs elsewhere.

As shown earlier, virtually all scientifically sound information about the effect of nutrition interventions refers to single interventions. Yet, the complex set of interacting determinants and strong synergism between and among various factors influencing the nutritional status lead to the conclusion that single interventions may not provide the most cost-effective strategy. Evidence from various integrated programs support this conclusion. Much more solid evidence is needed, however, to guide the design and implementation of the most appropriate integrated programs for the future.

Third, current attempts to deal effectively with the nutrition problem are hampered by a lack of a clear understanding about the most appropriate role of each group of key actors within a given socioeconomic and political environment. In some cases, agencies of national governments try to do what would be done more cost-effectively by the mother or the community, whereas in others, unreasonable expectations are placed on mothers to solve problems that can only be solved by agencies of a national government.

Attempts to provide predetermined solutions or magic bullets to solve problems that are poorly diagnosed frequently fail. Conversely, universal magic bullets are useful to remove certain constraints. The issue is to identify the constraints most effectively alleviated by generalized solutions and those requiring more specific solutions and to allocate available resources accordingly.

To do this, sound knowledge about household behavior related to food acquisition and intrahousehold allocation as well as health and nutrition-seeking activities is essential. Erroneous assumptions about the response of households to external influences frequently result in policies and programs that are poorly designed, poorly implemented, and cost-ineffective. Insufficient knowledge about the constraints to good nutrition at the household level adds to the problem. Finally, a better understanding of household coping strategies will greatly increase the ability to design appropriate strategies.

Research is also needed on the appropriate role of community action in alleviating health and nutrition problems. What type of action is likely to be most useful in various socioeconomic and political environments, and how can such action be most appropriately supported from outside the community? A great deal of lip service has been paid to community participation in primary health care and nutrition programs. In fact, much of such participation has been limited to the implementation of externally designed and controlled interventions. Community participation in problem diagnosis and the choice, design, and implementation of health and nutrition-related action that is sustainable without external material support has not been widespread, and research is needed to improve the understanding of how community action may be most effective.

With regard to research on the role of each of the key actors, there is an urgent need to improve existing knowledge about institutional and political economy factors and how these factors, including the behavior of various public and private sector agencies and groups, affect nutrition and nutrition interventions. The poor and malnourished usually possess very little political power and, although altruism may play a role, government action to alleviate poor nutrition effectively is likely to come about only if the nation as a whole or politically powerful groups within are perceived to gain. Therefore, the poor and malnourished must establish coalitions with more powerful groups. Furthermore, efforts to alleviate malnutrition must be institutionalized if they are to receive the necessary political support. Finally, information must be available to show the potential benefits to the various groups and to society as a whole, including additional analysis of the economic cost of malnutrition and cost-benefit and cost-effectiveness analyses of nutrition interventions.

Fourth, operational research is needed on a number of interventions to make available better information about what types of programs are likely to be most cost-effective under what conditions and for which population groups.

Fifth, certain biological and behavioral research is needed on the magnitudes and determinants of PEM among adult women, including but not limited to maternal depletion and how modifications in household behavior and access to resources may influence the nutritional status of women. This area has been almost totally ignored in the past. Finally, there is an urgent need for research on how best to deal with the increase of PEM as a result of economic crises and reforms and socioeconomic transitions, such as urbanization and associated changes in dietary patterns.

The above list of priorities for resource allocation and operational research should not be interpreted as being all-inclusive. Because PEM is influenced by such a complex set of factors, many more priorities could be listed. We have tried to list those that we feel are most important. We have not listed priorities associated with diseases discussed in other chapters in this collection, although many of them (for example, diarrhea and measles), are of great importance in PEM.

Appendix 18A. Estimating Nutritional Benefits

This appendix summarizes various ways to estimate nutritional benefits.

Estimating Economic Losses from Stunting

Carlson and Wardlaw (1990) report that 163 million preschool children are stunted. Of these, 41 percent, or 66.8 million, are severely stunted, whereas the rest, 96.2 million, are moderately stunted. Assuming a normal distribution and the standard deviation reported by WHO (1979), the height of severely and moderately stunted children at the age of two years is 10.0 and 7.0 centimeters below standard height, respectively. Martorell (in press) found that the absolute stunting in childhood measured in centimeters translates to an equal reduction in the height of adults. On the basis of a study of a sample of rural workers in the Philippines, Haddad and Bouis (1990) estimated the elasticity of labor productivity with respect to height of the workers to be 1.38; that is, a 1 percent difference in height is positively associated with a difference of 1.38 percent in labor productivity as measured by the actual wage received. The average height of the sample workers was 160.0 centimeters. Thus, 10.0 and 7.0 centimeters correspond to 6.25 and 4.38 percent of the height, respectively. Multiplying the elasticity and the height reduction due to childhood stunting yields estimated losses in labor productivity of 8.63 percent for severely stunted and 6.04 for moderately stunted individuals. Assuming a daily current wage of $2.50 and 300 working days annually, we arrive at an annual current wage income of $750.00 per person. The total economic loss as a result of stunting is then estimated as the total number of children stunted times the economic gain per individual, or a loss of $4.32 billion as a result of severe stunting and a loss of $4.36 billion as a result of moderate stunting. These figures yield a total annual economic loss of $8.68 billion.

Estimating Benefit-Cost Ratio of Preschoolers' Food Supplement

On the basis of results reported in table 18-9 it is assumed that a food transfer of 100,000 calories to malnourished preschool children results in an addition of 2.0 centimeters to the height of the child and that this height addition is maintained in adulthood. With reference to table 18-10, it is further assumed that the cost of the food supplementation program is $0.20 per 1,000 calories transferred. Thus, the cost per centimeter is $10.00. Using the above-mentioned estimates from the study by Haddad and Bouis (1990), one centimeter is equal to 0.625 percent of the height of the workers studied, and the corresponding increase in wages would be 0.625 x 1.38, or 0.86 percent. Under the above assumptions regarding daily wage and number of working days per year, this amounts to $6.45 per worker annually. Assuming that this wage gain begins at the age of eighteen, that is, seventeen years after the food supplement was received, and continues to age fifty-five, and using a discount rate of 3 percent and an annual increase in real wages of 2 percent, we arrive at $174.00 as the present value of the gain per worker, or a benefit-cost ratio of 17.4. For the purpose of sensitivity analysis, we estimated the benefit-cost ratios associated with height gains of 1.0 and 3.0 centimeters per 100,000 calories. The corresponding benefit-cost ratios are 8.7 and 26, respectively.

Estimating Cost per Child Death Averted by Supplement

Assuming a normal distribution and the standard deviation reported by WHO (1979), we estimated the prevalence of severe and moderate malnutrition from the average weight of the preschool children participating in food supplementation (table 18-9) prior to the supplementation (7.6 kilograms) and after a hypothetical average weight gain of 0.5 kilograms, which according to table 18-9 is brought about by a transfer of 100,000 calories. Based on the different mortality rates reported by Pelletier (1991) for severe and moderate underweight and using the prevalence of underweight reported in table 18-3, we estimated the effect of a weight gain of 0.5 kilograms on the overall mortality rate to be 1.03 percentage points. Considering this estimate as the reduction in the probability of dying, we estimated that the average cost of averting a child death would be $1,942, the cost of transferring 100,000 calories times 100 divided by 1.03.

Notes

1. These levels are not likely to be sufficient to cover energy expenditure associated with work and other activities desired by most people. Thus, they should be considered suboptimal in most cases.

2. Measurable responses may be less than expected by a purely factorial addition because physiological adaptations during pregnancy, such as changes in the resting metabolic rate and thermogenesis, may be altered by protein-energy malnutrition. Some of the improvement in dietary intake might be channeled into meeting the energy costs of these physiologic changes.

3. Weight at ages other than eighteen months and thirty-six months is not reported for Colombia in table 18-8 because the corresponding dietary intake was not reported for other ages.

4. The "conscientious efforts" were not specifically described.

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